Amendments to the Specification

In the paragraph starting on page 3, starting with "To solve the above described problems," please amend as the following:

To solve the above described problems, prior attempts include Japanese Laid Open Publication Hei 2-153679 which discloses a method of interpolating pixel color output values. Referring to FIGURE ~~2~~3, the R color-component values are interpolated in a one-dimensional single plane photo sensor strip as shown in FIGURE 1A. Since the R photo sensors exist only at positions 1 and 4, the R values are interpolated at positions 2 and 3 based upon the R output values at the positions 1 and 4. The following equations (1):

In the paragraph starting on page 3, starting with "Another prior art attempt," please amend as the following:

Another prior art attempt, Japanese Laid Open Publications Hei 2-239791 and Hei 7-123421 disclose methods for increasing resolution in image reproduction. The methods assume that a set of color-component specific photo sensors each has identical response sensitivity to achromatic light and that an image is achromatic. The intensity output from each photo sensor is now used for generating an image thereby increasing resolution. For example, referring to FIGURE ~~3~~4, even though individual photo elements are color-component specific such as R, G and B, only monochromatic intensity is considered. However, when the sensitivities are not identical and or the image is not achromatic, the sensitivities may be adjusted for a particular color component if relative color-component sensitivity response curves of the photo elements are known. The above described approach is useful only for a single color-component output and is not practical for chromatic images in general.

In the paragraph starting on page 7, starting with "FIGURE 5 is a block diagram," please amend as the following:

FIGURE ~~5~~8 is a block diagram illustrating a third preferred embodiment of the color resolution improving system according to the current invention.

In the paragraph starting on page 7, starting with "Referring now to the drawings," please amend as the following:

Referring now to the drawings, wherein like reference numerals designate corresponding structure throughout the views, and referring in particular to FIGURE ~~4~~5, one preferred embodiment of the color image improving system according to the current invention includes an image data input unit 110, an interpolation unit 120, a chroma value generation unit 130, a smoothing filter unit 140, an intensity estimation unit 150 and an output unit 160. The image data input unit 110 includes a single-plane photo sensor consisting of photo-sensitive elements such as capacitor-coupled devices (CCD). These CCDs are arranged in a predetermined spatial pattern on a single plane and generally each generate respective color-component specific signals such as RGB signals. The spatial pattern is either one-dimensional or two-dimensional. One example of the two-dimensional spatial pattern of the RGB photo elements is illustrated in FIGURE 1B.

In the paragraph starting on page 8, starting with "Still referring to FIGURE 4," please amend as the following:

Still referring to FIGURE ~~4~~5, the interpolation unit 120 interpolates RGB values in pixels whose color-component values are not measured. One preferred embodiment of the interpolation unit 120 according to the current invention interpolates the unmeasured values based upon adjacent measured values. One exemplary step of determining the interpolation values takes an average of the adjacent values. Another exemplary step of determining the interpolation values applies a predetermined mask or filter according to a specific pattern of the color-component specific elements to a measured value. Although

the filter may be applied to measured RGB values or chroma CrCb values, the preferred embodiment interpolates the RGB values.

In the paragraph starting on page 8, starting with "After the R0," please amend as the following:

After the R0, G0 and B0 values are interpolated to R, G and B values, a chroma value generation or chromaticity conversion unit 130 further converts the interpolated values RGB values to chroma values Cr0 and Cb0. One preferred embodiment of the chroma value generation unit 130 includes a 2 x 3 matrix containing coefficients which spatially correspond to a specific set of color-component photo sensor elements. One example of the matrix multiplication is described in the following equation (2) for enabling a conversion between the NTSC-RGB and Cr-Cb color space.

$$\cancel{\begin{bmatrix} Cr \\ Cb \end{bmatrix} = \begin{bmatrix} 100R - Y \\ 100B - Y \end{bmatrix} \quad \cdots\cdots (2)}$$

$$\begin{bmatrix} Cr \\ Cb \end{bmatrix} = \begin{bmatrix} 100R - Y \\ 100B - Y \end{bmatrix} \quad \cdots\cdots (2)$$

where RGB values range from 0 to 1 while Y ranges from 0 to 100. Furthermore, XYZ is defined as follows in an equation (3).

X *R* *60.69927 17.34486 20.05713*
~~*[Y] = M [G], M = [29.89665 58.64214 11.46122] ....(3)*~~
Z *B* *0.00000 6.607565 111.7469*

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = M \begin{bmatrix} R \\ G \\ B \end{bmatrix}, M = \begin{bmatrix} 60.69927 & 17.34486 & 20.05713 \\ 29.89665 & 58.64214 & 11.46122 \\ 0.00000 & 6.607565 & 111.7469 \end{bmatrix} \quad \ldots(3)$$

Where M is a 3 x 3 matrix. From the above equations (2) and (3), the relationship between the RGB and YCrCb values is described as follows in the following equation (4):

Y *R* *29.89665 58.64214 11.46122*
~~*[Cr] = N [G], N = [70.10335 -56.64214 -11.46122] ....(4)*~~
Cb *B* *-29.89665 -58.64214 88.53878*

$$\begin{bmatrix} Y \\ Cr \\ Cb \end{bmatrix} = N \begin{bmatrix} R \\ G \\ B \end{bmatrix}, N = \begin{bmatrix} 29.89665 & 58.64214 & 11.46122 \\ 70.10335 & -56.64214 & -11.46122 \\ -29.89665 & -58.64214 & 88.53878 \end{bmatrix} \quad \ldots(4)$$

where N is also a 3 x 3 matrix of coefficients. These coefficients are one exemplary set of values, and the matrix N is not limited to these particular values. Finally, Cr0 and Cb0 are determined more directly by the following equation (5).

$$Cr0 = n_{21} R1 + n_{22} G1 + n_{23} B1$$

$$Cb0 = n_{31} R1 + n_{32} G1 + n_{33} B1 \quad \ldots(5)$$

where ~~nij~~ n_{ij} is an element in the N matrix in the above equation (4).

In the paragraph starting on page 10, starting with "Still referring to FIGURE 4," please amend as the following:

Still referring to FIGURE ~~4~~5, in a preferred embodiment of the current invention, a smoothing filter unit or a low pass filter 140 generally smoothes out the converted chroma values Cr0 and Cb0 in the image data. However, the smoothing filter unit 140 is not limited to the chroma values, and it is implemented to be applied to RGB values in an alternative embodiment. The smoothing filter unit 140 is particularly effective on smoothing color output near edges. After the chroma values for each pixel are processed in the above described edge process, the intensity estimation unit 150 estimates an intensity value based upon the chroma values as well as the original RGB values from the image data input unit 110. In general, the intensity estimation unit 150 estimates the intensity value independently for each photo sensor position. In other words, the spatial arrangement of the color-component specific photo sensors are accounted for the intensity estimation. As a result, the intensity values range in a spectrum equal to that of entire photo sensors.

In the paragraph starting on page 10, starting with "In order to accomplish the above described tasks," please amend as the following:

In order to accomplish the above described tasks, the intensity estimation unit 150 solves for Y in the above equation (4) which relates the RGB and YCrCb color space. The intensity Y at a R color-component specific photo sensor position is determined as in the following set of equations (6):

$$Y = arR0 + brCr + crCb$$

$$ar = \left(n_{11} + \frac{n_{13}(n_{21}n_{32} - n_{22}n_{31}) + n_{12}(n_{23}n_{31} - n_{21}n_{33})}{n_{22}n_{33} - n_{23}n_{32}}\right)$$

$$br = \frac{n_{12}n_{33} - n_{13}n_{32}}{n_{22}n_{33} - n_{23}n_{32}}$$

$$cr = \frac{n_{13}n_{22} - n_{12}n_{23}}{n_{22}n_{33} - n_{23}n_{32}} \quad \ldots (6)$$

where R0, Cr and Cb are known variable while Y, ~~G and B are~~ is an unknown variable. n_{ij} is an element in the N matrix in the above equation (4).

In the paragraph starting on page 12, starting with "Now referring to FIGURE 5," please amend as the following:

Now referring to FIGURE ~~5~~6, areas such as an edge suddenly change in intensity, and the interpolation in these areas is not generally accomplished in an esthetically pleasing manner. Color-component specific photo sensors 190 are positioned in one dimension near an edge 701. Only intensity values of these photo sensors 190 are considered. Filled circles, squares and triangles respectively represent actual intensity

values of R, G and B photo sensors while unfilled circles, squares and triangles respectively represent interpolated R, G and B values. Near positions 2 through 5, the intensity values of the interpolated R, G and B values differ and have a color relation such as R > G > B. Consequently, near the edge, since the intensity values differ among the color components, inaccurate colors or intensities are reproduced. In order to substantially eliminate the above color-component discrepancy near edge areas, in one preferred embodiment according to the current invention, a smoothing filter unit includes a spatial filter whose function is described by the following equations (9).

$$Cr_i = \sum_{j=i-3}^{i+3} Cr0j/7$$

$$Cb_i = \sum_{j=i-3}^{i+3} Cb0j/7 \quad \ldots(9)$$

In the paragraph starting on page 13, starting with "Referring to FIGURE 6," please amend as the following:

Referring to FIGURE ~~6~~7, a second preferred embodiment of the color image improving system according to the current invention includes an image data input unit 110, an interpolation unit 120, a chroma value generation unit 130, a smoothing filter unit 140, a RGB value estimation unit 170 and an output unit 180. In the second embodiment, the G and B values are estimated assuming that Cr, Cb and R0 in the above equation are known variables. G and B values at a R color-component specific photo sensor position are determined based upon the following set of equations (10):

$$G = \frac{1}{n_{23} n_{32} - n_{22} n_{33}} ((n_{21} n_{33} - n_{23} n_{31}) R0 - n_{33} Cr + n_{23} Cb)$$

$$B = \frac{1}{n_{23} n_{32} - n_{22} n_{33}} ((n_{22} n_{31} - n_{21} n_{32}) R0 + n_{32} Cr - n_{22} Cb) \quad \ldots (10)$$

where n_{ij} is an element in the N matrix in the above equation (4). Similarly, the R and B values are estimated assuming that Cr, Cb and G0 in the above equation are known variables. R and B values at a G color-component specific photo sensor position are determined based upon the following set of equations (11):

$$R = \frac{1}{n_{23} n_{31} - n_{21} n_{33}} ((n_{22} n_{33} - n_{23} n_{32}) G0 - n_{33} Cr + n_{23} Cb)$$

$$B = \frac{1}{n_{23} n_{31} - n_{21} n_{33}} ((n_{21} n_{32} - n_{22} n_{31}) G0 + n_{31} Cr - n_{21} Cb) \quad \ldots (11)$$

where n_{ij} is an element in the N matrix in the above equation (4). Lastly, the R and G values are estimated assuming that Cr, Cb and B0 in the above equation are known variables. R and G values at a B color-component specific photo sensor position are determined based upon the following set of equations (12):

$$R = \frac{1}{n_{21}n_{32} - n_{22}n_{31}}((n_{22}n_{33} - n_{23}n_{32})B0 - n_{32}Cr + n_{22}Cb)$$

$$G = \frac{1}{n_{21}n_{32} - n_{22}n_{31}}((n_{23}n_{31} - n_{21}n_{33})B0 + n_{31}Cr - n_{21}Cb) \quad \ldots(12)$$

where n_{ij} is an element in the N matrix in the above equation (4). Thus, based upon the R0, B0 and G0 signals and the chromaticity values Cr and Cb, the RGB estimation unit 170 estimates the RGB values, and the output unit 180 outputs the improved RGB signals.

In the paragraph starting on page 14, starting with "Referring to FIGURE 7," please amend as the following:

Referring to FIGURE ~~7~~8, a third preferred embodiment of the color image improving system according to the current invention includes an image data input unit 110, a position counter 330, a coefficient set storage unit 310, a processing unit 320 and an output unit 340. The coefficient set storage unit 310 stores three sets of the coefficients. The position counter 330 determines a pixel position in question to be one of the color-component specific photo sensor positions based upon the number of counts on pixels and selects a corresponding one of the coefficient sets. The selected coefficient set is inputted into the processing unit 320. The processing unit 320 determines RGB values for each of the color-component specific RGB photo sensors at a photo sensor position i. In other words, the processing unit 320 takes the photo sensor position i into account in determining the RGB values.

In the paragraph starting on page 15, starting with "Referring to FIGURE 9," please amend as the following:

Now referring to FIGURE 9, to determine RGB values, for example, in reference to a R photo sensor at a position N, photo sensor values from positions ranging from a first position N-3 to a ~~second~~ fourth position N+3 are considered. In order to interpolate R values, a first set of R values ranging from a third position N-5 to a fourth position N-1 are considered while a second set of R values ranging from a fifth position N+5 to a fourth position N+1 are considered. In other words, in order to generate color image data in reference to the R photo sensor at the position N, eleven photo sensor values are considered. According to this preferred process, the RGB values the photo sensor at the position N are directly obtained from the above equations (1), (5), (6) and (10) through (12).

In the paragraph starting on page 20, starting with "An alternative embodiment of the preprocessing unit," please amend as the following:

$$\cancel{[\frac{Cr}{Cb}] = [\frac{Cr1\ Cr2\ Cr3}{Cb1\ Cb2\ Cb3}] \bullet [\begin{matrix} CCD1 \\ CCD2 \\ CCD3 \end{matrix}] \ldots (18)}$$

$$\begin{bmatrix} Cr \\ Cb \end{bmatrix} = \begin{bmatrix} Cr1\ Cr2\ Cr3 \\ Cb1\ Cb2\ Cb3 \end{bmatrix} \bullet \begin{bmatrix} CCD1 \\ CCD2 \\ CCD3 \end{bmatrix} \ldots (18)$$

In the paragraph starting on page 21, starting with "An alternative embodiment of the intensity estimation ," please amend as the following:

$$\begin{array}{ccccccc} Y & & C_R & C_G & C_B & & R \\ [Cr] & = & [1-CsubR & -C_G & -C_B] & \bullet & [G] \\ \cancel{Cb} & & \cancel{-C_R} & \cancel{-C_G} & \cancel{1-C_B} & & \cancel{B} \end{array} \quad \ldots\ldots\ldots(19)$$

$$\begin{bmatrix} Y \\ Cr \\ Cb \end{bmatrix} = \begin{bmatrix} C_R & C_G & C_B \\ 1-CsubR & -C_G & -C_B \\ -C_R & -C_G & 1-C_B \end{bmatrix} \bullet \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad \ldots\ldots\ldots(19)$$

$$CCD1 = R1 \bullet R + G1 \bullet G + B1 \bullet B \quad \ldots.(20)$$

where C_R, C_G and C_B are predetermined constants and R1, G1 and 1 are a portion of a matrix M in the following equation (21) by which the CCD values are converted to RGB values. The matrix M is determined based upon actual CCD measurements of known or measured RGB color image under pre/determined conditions and minimal square approximation.

$$\begin{array}{ccc} CCD1 & & R \\ [\,CCD2\,] = M \bullet [\,G\,] \ldots\ldots (21) \\ CCD3 & & B \end{array}$$

$$\begin{array}{c} R1\,G1\,B1 \\ M = [\,R2\,G2\,B2\,] \\ R3\,G3\,B3 \end{array}$$

$$\begin{bmatrix} CCD1 \\ CCD2 \\ CCD3 \end{bmatrix} = M \bullet \begin{bmatrix} R \\ G \\ B \end{bmatrix} \ldots\ldots (21)$$

$$M = \begin{bmatrix} R1\,G1\,B1 \\ R2\,G2\,B2 \\ R3\,G3\,B3 \end{bmatrix}$$